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south as the latitude of Philadelphia, either by cold or long drought, or both.

Professor Trego gave an account of the destruction in Germantown.

Mr. Blodgett added his notes of the Meteorology of March 5th, 6th and 7th, during which a cold, dry gale prevailed, to which he ascribed the loss of these plants. Fruit trees, when their time for flowering arrived, showed an inability to blossom for several weeks, as if paralyzed; the dryness of the gale of March seemed to have exhausted the sap. Many of the White Pines of the Alleghany Mountains were also killed.

Pending nominations, Nos. 693 to 696, and new nomination, 697, were read,

And the meeting was adjourned.

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NOTE ON A FINE UPTHROW FAULT AT EMBREEVILLE FURNACE IN  
EAST TENNESSEE.

BY J. P. LESLEY.

(*Read before the American Philosophical Society, May 3d, 1872.*)

In a late visit to the works at Embreeville, on the Nolichuckee River, in Washington County, East Tennessee, I made a compass and barometer survey of the river valley and Bompas Cove, connecting the Furnace with its flux quarry and ore banks, tram road, washing ground, slack-water channel, etc., which will be found delineated on the accompanying map, drawn on a scale of 4,000 feet to the inch, with contour lines of 20 feet elevation to express the topography.\*

\* The accompanying map was hastily sketched for reproduction by Mr. Bien's photo-lithographic process. It merely shows the character of the topography of a portion of the property. But it is accurate so far as regards the course of the river, the hills which enclose it, the sand-rock outcrops, the north end of Bompas Cove, the grade contours of the railway and ravines, the elevation of the mines, &c. All the rest, including the heights and contours of the mountains, must be considered merely approximations to the truth. The contour lines represent elevations of 20 feet successively above tide-water, commencing at about 2,000 feet. The section below the map represents the geology along the river, above and below the Furnace. The scale was originally 1,000 feet to the inch. It was photographed down to 3,000 to make a plate. That plate was lost in the fire which rendered a second edition of this Number of the Proceedings necessary. An original copy from the first plate was then photographed down to 4,000 feet to the inch, to make the present plate.



Scale 4000 ft. to the inch.

The Furnace stands in the gap which the Nolichuckee makes through the last range of mountains on its way out from the North Carolina Highlands to the Great Limestone Valley of East Tennessee. A double rib of massive sandrock here forms a natural dam and mill-race, affording unlimited water-power, protected by projecting fragments of the sandrock outcrop from the most violent freshets. It is a scene of rare beauty, and a remarkably favorable location for any kind of industry requiring power. A broad terrace affords ample room for several furnaces and their dependent outworks, a village, mills of different kinds, and, in fact, for a Rolling Mill of the first class.

At present there stands here one Furnace, of small size, making  $6\frac{1}{4}$  (six and a quarter) tons of metal per day at the time of my visit, a saw mill, an ochre mill, a village, store, church, and Superintendent's mansion.

A rope-ferry communicates with the State Road on the opposite shore. Jonesborough—the capital of the county, and oldest settlement in the State, on the East Tennessee, Virginia and Georgia Railroad, 32 miles from Bristol, 98 from Knoxville, 210 from Chattanooga, 236 from Lynchburg, 440 from Norfolk, and 391 from Richmond—is eight (8) miles distant from the furnace by this State Road. A railway could be made without difficulty over these eight miles, along smooth vales of limestone land, which head up towards Jonesborough. My barometer along the State Road gave me 200, 300 and 340 feet as the summit elevations above the river at the ferry. The intervals were from 50 to 100 feet lower. Railroad grade at Jonesborough was something under 200 feet above the ferry. A line might be located with maximum gradients of 50 feet to the mile, and with little or no cutting and filling, except for the first half mile below the furnace in the gap. Ten or twelve thousand dollars a mile ought to be quite sufficient to build the road. The bridge at the Furnace would be 200 feet long, but would need no piers, nor abutments: these being provided by nature in the shape of colossal sandrock outcrops rising fifty feet above the river bed.

The metal made at the Furnace goes chiefly to the Tredegar Works at Richmond, 400 miles from the Furnace, costing \$3.25 a ton to haul to Jonesborough, in the present state of the roads. In dry seasons, the limestone roads become smooth and hard.

Up the river to the south and east, locked in among hills of irregular trend, steep slopes, and bluffs of crumbling rock, from 600 to 1,000 feet high, lie two limestones coves: Bompas Cove, drained by Bompas Creek, flowing north into the river at the Furnace washing ground, two miles from the works; and Greasy Cove, drained by streams flowing southwestward to the river, and about six miles from the works.

Bompas Cove is an oval valley three or four miles long, by one and a-half wide at its widest part, surrounded by mountains about a thousand feet high, on the inner slopes of which rest terraces or hill-spurs of decomposed limestone (Lower Silurian) holding masses of brown hematite iron ore of two varieties; the lower series (and outer, or closer up to the

mountain wall) being silicious and cold-short, and the upper series being argillaceous and red-short. The cove is nearly encircled by the cold-short deposits, which have been opened in a number of places, and a good deal mined, towards the head of the cove, for an old furnace further south. The red-short hematites are extensively spread out more in the middle of the cove, where they are capped by lead-bearing members of the Limestone formation.

There are a few fertile farms in the cove ; but an uninterrupted forest covers all the mountain country around it, most of which is included within the limits of the estate.

Greasy Cove is a large and nearly level limestone plain, more than twenty miles long by five miles wide, similarly surrounded by shale and sandstone hills nearly 1,000 feet high and backed by the State Line Range of the Unaka (Sub Silurian) Mountains more than twice as high. The Nolichuckee enters this cove from the mountain country to the south, and leaves it by a gorge, the south wall of which is a towering cliff of sandstone 500 or 600 feet in vertical height, called the Devil's Looking Glass. It flows thence three miles straight north-northwest towards the mouth of Bompas Cove, where it makes an ox-bow, and then flows north to the Furnace, as shown in the map.

This interval of three miles is made through forest-covered hills. Paddy's Creek and Broad Shoals Creek form narrow forest-covered valleys, entering the river valley from the southwest. Another stream of equal size forms a similar valley on the northeast. All this is good coaling ground for iron-works ; and depots of charcoal can be established at different points on the two banks of the river, down which the fuel can be safely and cheaply boated. Two large charcoal furnaces at Embreeville could be erected in view of a constant supply of charcoal by the organization of an extensive system of coaling depots up the river. A forest surrounds the head of Greasy Cove and passes in an unbroken belt across all the hill country back of the river bottoms, over to the *Dry Creek Valley*, and Buffalo or Cherokee Mountain, north-northeast and east of the Furnace. This is on the east side of the river. On the west side, as I have said, many square miles of forest-covered hill country surrounds Bompas Cove.

This forest consists of white oak, spruce pine, poplar, hickory, etc., most of it in its original condition. Some tracts have been coaled off once, others twice. After fifteen or twenty years they are ready for coaling again. I saw a few trees two feet in diameter ; but the forest trees are lighter than I am accustomed to see in Pennsylvania. They will probably yield, on an average, 40 or 50 cords to the acre, while some ravines will go up to 100.

The charcoal used at the Furnace is good and strong, but by the hauling over steep roads, and several handlings, the waste amounts to 25 or 30 per cent. Most of this could be saved under a more extensive and complete organization of this part of the business, and by the use of

large baskets on trucks. The coal floors are near enough the Furnace to allow the carts to go to it twice a day ; some, however, can be reached but once a day. The dependence of extensive works must be on a river navigation and coaling depots above, as has already been said.

One hundred and ten bushels of charcoal go to the ton of iron at this furnace, making, say, six tons. An enlarged stack could easily make ten or twelve. The Shelby Furnace in Alabama, sixty feet high, is making at the present moment, with charcoal, sixteen (16) tons, by information I have indirectly from the keeper, although it is reported she has made twenty. The report is incorrect ; she has never exceeded sixteen. But this shows what *can* be done with charcoal and brown hematite ore. In smelting rich fusible lump ore, one ton of metal requires from *one-third* to *one and a-quarter* tons of hard charcoal, or from *one and a-half* to *three* tons of soft charcoal.

*Coke*, however, is the future dependence of Embreeville Works on an extensive scale. The Cumberland Mountain, west of Knoxville, (Coal Creek, Cove Creek, etc.,) has numerous workable beds of good bituminous coking coals. The Knoxville and Kentucky Railroad is already carrying these coals from the mines to the factories and ironworks of Knoxville and other towns along the East Tennessee Railroad, including Jonesborough. Contracts can be made for the delivery of any amount of Cumberland Mountain (Waldron Ridge) coal at Jonesborough, for \$3.25 to \$3.50 per ton. If the eight mile branch to Embreeville were built, costing with bridge and rolling stock, say \$150,000, the coal could be landed at the Furnace at a cost of something under \$4, and there coked ; or, which would be better, coking establishments could be organized in the Cumberland Mountains, along Cove Creek, and the coke be deposited at Embreeville for about \$4.50, owing to the fact that—1. One-half the weight of the car-load would be saved by carrying it in the form of coke ; 2. The waste in dust would be saved ; and, 3. The slake waste at the mines would be coked with the lump.

Now,  $6\frac{1}{4}$  cents a bushel is paid at the Furnace for charcoal, or,  $6\frac{1}{4} \times 110 = \$6.87\frac{1}{2}$ , to make a ton of metal.

Coke furnaces require from 1.1 to 2.3 tons of coke to make 1 ton of iron, according to their size, shape, and especially the quality of ores employed. For brown hematites it would not be safe to assume less than  $1\frac{1}{2}$ , and it might go up to  $1\frac{3}{4}$  tons of coke to one of metal. If coke could be got at Embreeville for \$4.50, the coke for 1 ton of iron would still cost \$6.75, as against \$6.87 $\frac{1}{2}$  for charcoal.

But while a charcoal furnace is producing 45 tons of metal a week, a coke furnace with hot blast is producing from 150 to 200 tons a week.

It would be unwise to erect more than two first-class charcoal furnaces at a point like Embreeville, in view of the extensive and complicated system of coaling and boating required. These would make 10 tons a day each, or 140 tons of metal per week. Whereas four coke furnaces might

be put in blast safely, making together (with one always out for repair, etc.), say  $3 \times 150 = 450$  tons of metal per week ; or even 600 or more.

On the other hand, no profit could be made on coke bought at the mines ; and no profit on coal, but only on the coking of the coal at the Furnace, by supplying store goods for wages ; whereas, the  $6\frac{1}{4}$  cents per bushel paid for the charcoal is paid in stores, and a large saving accomplished.

The same is true of other labor, at the Furnace and at the mines ; but this would not be changed by the substitution of coke for charcoal.

Another consideration, and one of importance, is the change in the quality of metal produced. So long as the lowest beds of the Cumberland Mountain system are mined, the coal will be second rate, and even if the best precautions are taken, the coke will not be so good a fuel as charcoal. Quality of metal would have to be sacrificed to some extent for the sake of quantity. The metal made at Embreeville could hardly be better than it is ; exceedingly strong in the pig and much esteemed for car-wheel use. The price of such iron must always be high, whatever be the state of the seaboard and foreign markets, because of the limited amount of it made, and always to be made. Much, if not most, of the Tennessee iron must always be cold-short on account of the wide distribution of cold-short ores through the country.

The Brown Hematite, or limonite, deposits of Bompas Cove exactly resemble those of Morrison's Cove, Nittany Valley, Kishicoquilis, and other Lower Silurian limestone valleys of Pennsylvania and Virginia ; and those of the long line of the north flank of the South Mountain (Blue Ridge, Smoky Mountain range) from the Hudson River to Alabama. They are in fact situated geologically just like the Allentown, Carlisle, and Chambersburg deposits.

These ores are irregular masses of ochreous clays and loose sands, full of shot and balls and pipes of the hydrated sesquioxide of iron ; with coatings of the black oxide of manganese, and traces of the original sulphide of iron, sulphide of lead, and sulphide of zinc, held by the limestone strata before these were dissolved and made cavernous by the drainage waters which have packed the clay sand ore into all the holes and crevices, caves and water-courses thus made.

The general dip of the limestone beds in Bompas is about  $10^\circ$  north-northeast, against a fault which crosses the mouth of the cove and seems to run in a line about N.  $15^\circ$  W., S.  $15^\circ$  E. All the rocks to the east of this line—the rocks in which the river flows—are of an older age, and dip  $60^\circ$  S.  $40^\circ$  E., in very straight bold outcrops, as represented on the map and in the section accompanying it.

This gentle dip of the limestone has exposed several square miles of the ferruginous lower limestone to decomposition ; and the quantity of ore is correspondingly great.

The limestone has been cross-cleft ; its cleavage planes dipping  $45^\circ$ , more or less. The dissolution has followed these cleavage planes. The

ore-clays are packed in descending cavities sloping at that angle. The massive ore seems to dip  $45^{\circ}$  therefore, instead of  $10^{\circ}$ . But as several hundred feet of the nearly horizontal limestone beds has converted itself more or less into ore, the quantity of ore is immense.

The series of ore pits from which the furnace has supplied itself, ranges up the side of a steep hill, beginning at an elevation of about 200 feet above the river (one mile from it), and ending at an elevation of 350 feet. But the ore continues up the hill a hundred feet higher; and descends also below the lowest pit. No system has been observed in mining the ore. Everything has been done hap-hazard and in the most expensive way.

The stripping varies from a foot or two to twenty and thirty feet. The solid ore-ground, consisting of from one-half to four-fifths fine ore, the rest balls, with occasional masses of clay, and occasional masses of solid hard limestone rock (left in its original condition, but with all the edges dissolved round), has been dug into to a depth of ten, fifteen, twenty feet, and more in places, without reaching bottom.

I judged that I saw along the line of pits over the end of the tramway, about one million of tons of ore.

The ore can be followed over the top of the little hill and down its northern side.

Abundant evidence of ore covers the long slope of the hill towards the south for a quarter of a mile.

The same limestone beds take into the isolated hill to the west; and on both sides of this hill near its top are old diggings of the ore, from which the original furnace was supplied for a good many years, and abandoned when that furnace was abandoned, and the new Furnace was erected at Embreeville. The old furnace was situated on Bompas Creek, about half a mile southwest of the present ore mines, and just opposite the lead mine shown upon the map, but inconveniently far from the river.

There must be millions of tons of iron ore in the more central part of the cove, in the low hills composed of the almost horizontal ore-bearing limestone strata, which everywhere show the dissolving action of the ore-collecting waters, and are covered in many places with ore-ground.

The books of the Furnace show that after the ore has been washed and the large lumps roasted to make them more easily broken to pieces, the lowest percentage of ore to pig metal is 49, and the highest 59. The *practical average* of pig iron obtained from the thus prepared ore is fifty-five per cent.\*

\* Analysis of Brown Hematite ore from Bompas Cove, E. T., made by Prof. Fisher, of U. S. Naval Academy, Annapolis, Md.:

Water and organic matter,	-	-	-	-	-	-	-	-	13.15
Phosphoric acid,	-	-	-	-	-	-	-	-	.09
Silica,	-	-	-	-	-	-	-	-	3.05
Alumina,	-	-	-	-	-	-	-	-	1.28
Sesquioxide of manganese,	-	-	-	-	-	-	-	-	.27
Sulphur,	-	-	-	-	-	-	-	-	.203
Peroxide of iron,	-	-	-	-	-	-	-	-	82.27

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100,313

82.27 peroxide of iron equals 57.6 per cent. pure iron.

The weight of the washed ore when dry is one and a half ( $1\frac{1}{2}$ ) tons to the cubic yard. The weight of the lump ore is about  $1\frac{1}{4}$  tons to the cubic yard. One car-load of 44,919 cubic inches measurement, *thoroughly dried wash ore*, weighed 3,042 lbs. One cubic yard = 46,656 inches. The lump ore of one car weighed 2,570 lbs.

Very little flux is required by the Furnace, and this is obtained from bold outcrops of blue limestone on the State Road two-thirds of a mile north of the ferry. There is so much lime in the wash ore and in the clay of the ball ore, and so heavy a charge of manganese in the ore deposit that the fluxing of the stock scarcely adds to the expense of its smelting. The cinder is excellent and the waste of iron is evidently small.

Around the inside lining of the tunnel head for about four feet down from the lip of the filling-hole, there forms a coating of concentric layers of a very solid and heavy substance, consisting chiefly of metallic zinc, in alloy with metallic lead and a small quantity of metallic iron.\*

The upper and more solid blue and white limestones of Bompas Cove, exposed along the banks of the creek, opposite the old furnace site, contain a good deal of disseminated galena. This is decomposed into carbonate of lead, filling crevices which have been followed down by shafting operations during the late war. The two ores of lead were taken in cars, on a tram road a few hundred yards long, down the creek to a lead mill erected by General Jackson, and there smelted for the use of the Confederate army. The works are now abandoned, and the shafts filled with trash or water.

Brown hematite iron ore deposits have also resulted from the decomposition of the limestone beds over the lead-bearing strata.

Greasy Cove is a district of limestone similar to, but much more extensive than Bompas Cove, and carries the same brown hematite iron ore deposits of probably equal size. The hills overlooking the flat land of this cove on the northwest and within half a mile of the river, are red with ore.

\* Analyses, by Persifor Frazer, Jr., Assistant Professor of Chemistry in the University of Pennsylvania, of—

I. *Furnace product* from Embreeville Works, N. C., taken from within four feet of the tunnel head: A hard, brittle, gray solid, with occasional streaks of green, but in powder is grass-green. Specific gravity, 5.6.

Under the magnifying glass it shows minute metallic scales which impart a metallic lustre to the streak when the product is scratched, and yet bear such a small proportion to the whole mass that they are almost indistinguishable with the naked eye.

Silica,	-	-	-	-	-	-	-	-	0.28
Iron (calculated as sesquioxide),	-	-	-	-	-	-	-	-	4.12
Zinc (oxide),	-	-	-	-	-	-	-	-	84.26
Lead (metallic),	-	-	-	-	-	-	-	-	6.18
Carbon (as finely divided coal dust determined by loss),	-	-	-	-	-	-	-	-	5.16

II. *Lining stone* of Embreeville Furnace, N. C. A yellow sandrock used for the lining of the Embreeville Furnace, and remarkably lasting, was proved to contain:

Silica,	-	-	-	-	-	-	-	-	76.99
Alumina and Iron (latter under 2 p. c. $\text{Fe}_2\text{O}_3$ ),	-	-	-	-	-	-	-	-	16.12
Magnesia,	-	-	-	-	-	-	-	-	2.63
Lime,	-	-	-	-	-	-	-	-	1.44
Undetermined,	-	-	-	-	-	-	-	-	2.83

Considerably more than 50 per cent. of the Silica given above seems to exist as free Silica, or sand.

These details are not only interesting in themselves, but necessary for familiarizing the observer with the scene of a geological action, common enough in our Appalachian region, but rarely exhibiting itself in so bold and telling a way as at Embreeville.

A fault—an upthrow and overshove—a collapsed synclinal at the edge of the thrown-down mass—all this is presented to the eye of the structural geologist, as he stands on the steps of the little Church of Embreeville and looks across the river eastward. Hundreds of feet of limestone outcrop, in part natural cliffs, in part quarry work, demonstrate the problem of Cambrian overlying Silurian—the Quebec Group overriding Trenton Limestone—by drawing it in a grandly visible diagram, a mile long, by 800 feet high.

The solid plates of limestone are bent round in the synclinal without fracture (other than at the great cleavage planes) as though they had been as plastic as wax. A slight anticlinal roll immediately precedes the sudden upturn to a vertical followed by a declining angle in the reversed sense. The exact place of the fault is obscured by a general crush and sheet-covering of the finely broken shale and very thin bedded shaly sandstone layers which make the rest of the mountain mass.

Up through these sandy shales, dividing them into an upper and lower system, rise the bold outcrops of two conglomerate beds, each about 20 feet thick. One of them, forming the crest of the mountain east of the river, descends in a dyke to the water, sinks under the valley, and reappears to face the slopes at the bend at the mouth of Bompas Creek. The other forms a dyke along the foot of the mountain from the Furnace southwest to Bompas Cove. These two coarse sandrocks or finely brecciated conglomerates are shown in the diagram at the foot of the map on page 445, above.

It will be noticed that another set of sandrocks, not at all conglomerate, but semi-crystalline in texture, and (with alternations of softer kinds, and shale bands) at least 100 feet thick, come in above and (being nearly horizontal) cause that hog-back topography seen in the horseshoe bend of the river. It will be noticed also that above these last sandrocks, lies a third or uppermost system of sandy shales. These constitute (with some still higher intercalated massive sandrocks) the bulk of the inwalling river hills (600–800 feet high) all the way up (about 3 miles) to the entrance into Grassy Cove; that is, to the next parallel fault throwing down the Silurians.

It will be evident to those familiar with this characteristic structure of East Tennessee and Southwest Virginia, that the Nolichuckee River exposes a nearly transverse cross-section of a long prism of earth-crust composed of sandy shales, sandrocks and conglomerates, at least 600 feet thick, *elevated* between enclosing *sunken* countries of Lower Silurian Limestone.

There is no sign of squeeze and distortion along the southern (Greasy Cove) fissure, for the uplifted upper shales abut there horizontally against

the down-thrown limestone prism to the south of it. Whereas in the Embreeville (or northern) fault, the lower part of the shale prism has been lifted and thrust violently against the limestone prism to the north, so as not only to override it, but to curl up the ends of its beds into a collapsed synclinal. The force has therefore come from the south, and acts northward, or north-northwestward. This is not only in accordance with the law of anticlinal structure, made out in Pennsylvania by the survey under Prof. H. D. Rogers, 35 years ago, but with nine-tenths of the fault exhibitions in Virginia and Tennessee.\*

What the rock system is, a prism of which has thus been upheaved between the two Lower Silurian districts of Jonesborough to the North, and Greasy Cove to the South, is still a subject for discussion. Mr. Safford, State Geologist of Tennessee, gives it the name of Chilhowee, without identifying it closely with any of the great Formations of the Northern States. It probably underlies immediately the Lower Silurian Limestones.

One thing is remarkable: its apparent total lack of iron ore and limestone. There is no appearance of metamorphism throughout the 6,000 feet of rock trenched by the Nolichuckee.

The cross-fault of Bompas Cove, on the west side of which the L. Silurian Limestones are dropped to water level in an almost undisturbed (horizontal) condition, is, perhaps, the most interesting feature of the dynamic scene I am trying to portray; but it must remain for some geologist to study who has more time at his command than I had, in my hurried visit to Embreeville.

These cross-faults are incidentally mentioned by Mr. Safford, on page 200 of his Report of the Geology of Tennessee for 1869, when he says:

"484. At the ends of these mountains, the sandstones which form them are suddenly and curiously cut off, and wholly disappear. The mountains and their rocks, of course, lie generally immediately on the southeast side of a fault. The sandstones, broken in wide blades, appear to have been thrust up endwise to the northwest, through the overlying formations. The displacement is, in some cases, very great. In the case of Chilhowee Mountain (see section page 190), the sandstones, or, rather, Ocoee conglomerates, have been brought up and abutted against *Carboniferous Limestone*."

The expressions used in the above description are calculated to obscure the picture to the eye of the reader. The sandstones are prominent objects in the landscape; but they are integral and very subordinate items in the mass of the upthrown (and often but slightly tilted) prism of earth-crust. To a depth unknown to the observer, the earth-crust in all this region of Virginia and Tennessee has been cracked along straight, parallel lines of great length (some of them a hundred miles), but of no

\* I have recently exhibited to the Society cross-sections of this structure, in Tasewell, Wise, and Scott Counties, Virginia, which, when published in the next Number of these Proceedings, will make this law sufficiently comprehensible.

great width, seldom over five miles. In Mr. Safford's Section (page 190), across Eastern Tennessee, from the carboniferous table-land, southeastward to the Metamorphic Azoic Mountains of the North Carolina line, 52 miles, there are *eight* of these faults noted, making the average width of each prism (supposing no fault has been omitted)  $6\frac{1}{2}$  miles.

The upthrow or override of the side face of each prism against the prism to the northwest of it, varies from fifteen thousand (15,000) feet (as in the Chilhowee Mountain Fault above cited, and in the Montgomery and Wythe County Faults of Virginia) down to five thousand, as in the case of the Embreeville Fault, and others of a like kind, in the same range, where the bottom measures of the Chilhowee, or top measures of the Ocoee, Formations abut against the Trenton Limestones.

The tilt of a prism, five miles wide to an elevation of only one mile on its northwest border, gives an average dip of 1 in 5, or  $10^\circ$ . But the tilt has been produced by a thrust from the southeast, violent enough not only to produce the tilt, and thrust the prism forward and upward, but to rub up the broken edges of the layers of the down-tilted next prism, and to rub down the broken edges of its own layers; and, moreover, to bend the whole body of the prism along its northwestern limit. Consequently we have *there* dips of  $45^\circ$ , whereas the dips everywhere else (with trifling exceptions) are scarcely more than  $5^\circ$ .

It may be said, therefore, if astonishment be expressed at the vastness of these upthrows, considering the weight of the prism, that, in fact, there has not been so much upward movement after all.

On the other hand, in the sections I have made across sets of these faults, in other parts of the region, and where the uptilt is of lower Silurian Limestone against Coal Measures, repeated again and again, the proportion of horizontal to vertical is as 5 miles to 3 miles, and a dip of  $30^\circ$  pervades the entire body of the prism, and of *each* prism, from side to side.

This is a very astonishing state of things. And it characterizes a region of country fifty miles wide by five hundred miles long, roughly stated.

What supports these long untilted prisms of earth-crust?

We cannot imagine an underground Pre-silurian topography arranged with such regularity, as to allow the settlement of the sections of Paleozoic series, in straight lines, hundreds of miles long, and always on one side, the southeastern.

It seems to me evidently necessary to assume a (in some sense) plastic underground, on which these wonderfully regular prismatic rods of Paleozoic rock have been able to roll one-third over and adjust themselves.

The alternative must be, that the vacancies (of triangular section) have been filled with the debris of the lower crushed edges and bottoms of the prisms,—a most unsatisfactory suggestion—especially unsatisfactory, because the regular over-roll of all the prisms in one direction

proves that the laterally acting energy (whatever may have been its origin) was acting on a great plate of Paleozoic rockmass, at least (counting in the coal measures) *four miles thick* ; solid, although flexible, itself ; but free, when broken, to slide on its foundations, as the broken up flakes of ice slides over the water which supports them.

That there was no absolutely fluid (lava?) underground beneath them is evident from the total absence of volcanic rocks at the present eroded surface, along these faults, even when the uppermost *Subsilurian* rocks appear in one wall. (The numerous warm springs connected with the Virginia faults are explicable on chemical principles, no doubt.) But beneath the uppermost *Subsilurians* are vast formations, all more or less metamorphosed, and many converted into granites and other crystalline forms. Here we have the plastic mass we need, over the surface of which (of course, an eroded surface, but, probably, eroded to a plane containing no Alpine or even Subalpine inequalities) the Paleozoic deposits, consolidated by time into a consistent, but never yet dried, sheet, seven miles thick in Pennsylvania, five miles thick in Virginia, three miles thick in Tennessee, moved with a certain freedom, under a lateral pressure, from the southeast, at the close of the Coal Era.

I have formerly taken occasion to ascribe the difference of effect exhibited by this pressure in Pennsylvania and in Tennessee to the difference in the thickness of the Paleozoic mass. In Pennsylvania it was folded ; in Tennessee dislocated. But the difficulty which pressed on Mr. Rogers to explain the sustentation of the vaults of our Northern anticlinals, is encountered equally by the Southern geologist who will explain the stable equilibrium of his tilted prisms.

To return from this digression to the cross fissures, which cut off the ends of the Chilhowee and other mountains (and an example of them is given in my map of Bompas Cove), it must be understood that they do not obey one law, as do the principal and parallel dislocations of the country. They sometimes run square across from one of these to or towards another ; seldom cutting a prism entirely off ; usually cracking its north western edge for a certain distance into its body. It is a subordinate and secondary system of faults. But by means of it most of the Appalachian ridges or mountains, of Middle Silurian and Upper Devonian age, are swallowed up and ended at the surface ; just as are the mountains of Chilhowee sandstones, in such cases as that described by Mr. Safford above.

The section accompanying my map will, perhaps, be compared by some reader of this paper with Mr. Safford's section on page 202, and they will be seen to be very different. It is only needful to explain that my section was made with instruments on the ground under favorable circumstances, and carefully drawn to the same horizontal and vertical scale ; whereas the section on page 202 is like Mr. Safford's other sections, drawn to a vertical scale at least twenty times greater than the horizontal, and, as he says, "it is not intended to be accurate in detail."

In fact nothing can be more erroneous than the impression on the mind

of a young geologist produced by the section. It not only distorts the facts, but bars the way to a right understanding of the structure not only of this locality at Embreeville Gap, but of similar localities along the Unaka Mountain range.\* There are no such syndinalas as are there represented. There is nothing which in the remotest sense resembles the anticlinal there drawn under the letter D. That interval is essentially and wholly monoclinial.

Every student of American geology must acknowledge his great indebtedness to the assiduous and judicious State Geologist of Tennessee, who has done so much to elucidate one of the most interesting regions of the United States. Among the many valuable columns of thicknesses which he has published, the following (in § 489) justifies the statement I have made relative to the amount of rock visible along the river above Embreeville. It represents the Chilhowee Group, in Doe River Gap, Carter County.

Top of Section :—Quartzose sandstone.....	55 feet.
Sandstones and Shales.....	70
Quartzose Sandstone.....	10
Sandstone and Sandy Shales.....	250
Quartzose Sandstones.....	35
Sandstones and Sandy Shales.....	370
Quartzose Sandstone.....	40
Thick and thin bedded Sandstone, generally dark colored, occasionally Sandy Shales, and but little fine conglomerate.....	1,720
Quartzose Sandstone.....	40
Thin Sandstones and Sandy Shales.....	320
Sandstones and fine conglomerate with two Quartzose bands.....	275
Heavy bedded Quartzose Sandstone.....	38
Sandstone not well seen.....	180
Heavy Gray Quartzose Sandstone, with unimportant layers of fine conglomerate.....	60
Sandstones with conglomerate, dark and even bedded...	44
Heavy Gray Quartzose rock, mostly sandstones with fine conglomerate.....	60
Some of the Sandstone hard and Quartzose.....	472

The lower part of my Embreeville Section consists of between one and two thousand feet of sandy shales, with two very massive plates of conglomeratic sandstone, about twenty feet thick. Two or three thousand

\* With the highest respect for the distinguished services rendered our science by the State Geologist of Tennessee, I cannot refrain from expressing regret that the weight of his standing in the science should be thrown into the scales on the side of the slovenly and mischievous fashion of distorted drawing in vogue among geologists until recent years. A section is worse than worthless which is not well and truly drawn. It is sure to manufacture and perpetuate false views.

feet more, higher up, consist of massive sandstones and heavy beds of shale alternating. Just overlying the upper conglomeratic sandstone plate are variegated clay slates.

It is impossible not to see the significance of the immense development of sandrocks and pebble rocks, in the Ocoee and Chilhowee systems, underlying the Lower Silurian Dolomites, and hugging the flank of the backbone of the Continent, for a thousand miles through Virginia, North Carolina, Tennessee and Georgia, as in New Jersey and New York. It is a shore deposit on an immense scale, in a shallow sea, with a steeply inclined margin, and an Alpine range inland. No glaciers; for the conglomerates consist of rolled shingle stones; but torrents, innumerable and vehement. No large rivers; for no delta deposits of any size are apparent. A rapid degradation of the mountains was followed or stopped by a partial submergence, which deepened the sea, made the sand deposits finer, and permitted the deposit of the Lower Silurian limestones.

The reason therefore why the massive Quebec Group (Potsdam, Chilhowee and Ocoee) formation does not come up to daylight in the faults which break the middle and northwestern parts of the floor of the region under discussion, is because it thins away rapidly seaward, that is, westward, towards the Coal Area. And in this it only sets an example afterwards followed by the sandstone and conglomerate members of the great Palæozoic system: Nos. IV, IX, X, and XII the Millstone Grit.

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*Stated Meeting, July 19, 1872.*

Present, five members.

Mr. ELI K. PRICE, in the Chair.

A photograph for the Album was received from Prof. Thomas Chase, of Haverford, Pa.

Letters acknowledging receipt of publications were received from the Royal Society, London (86, 87). The Royal Saxon Society (86); the Zoologico-Botanical Society, Vienna (Vols. 8 to 11 Proc., and Trans. Vols. XII, XIII, XIV, i, ii, with a request to have the set completed. On motion, referred to the Librarian); and from Dr. Hornstein, Prag. (86).

Letters of envoy were received from the Observatorio de Marina de S. Fernando, and the Physico-Medical Society in Erlangen.